EUV Resist Material and Process Development at EIDEC

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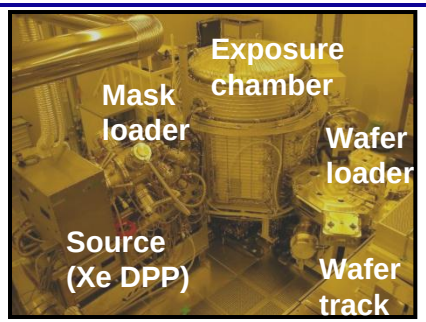
Outline

1. Introduction
   - Previous Work on EUV Resist Material and Processes
2. Update of the EIDEC Standard Resist
3. Analysis of the Origin of RLS Trade-off on EUV Resist
4. Fundamental Study of Development Process
5. Summary

Introduction

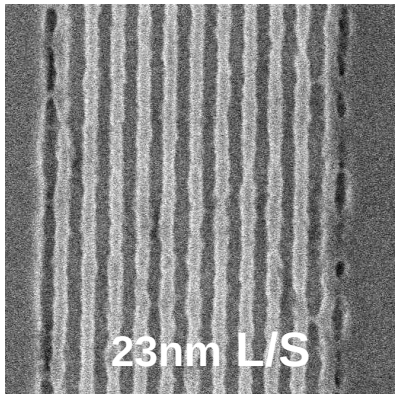
Previous Work on EUV Resist Material and Processes

1. Selection of EIDEC Standard Resist (ESR1)
2. Novel rinse process for pattern collapse prevention and LWR reduction
3. Fundamental study of development by HS-AFM

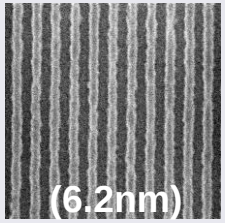
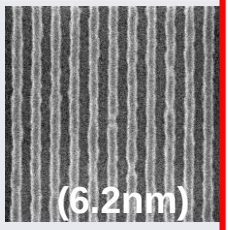
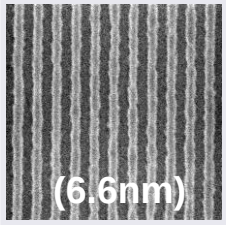
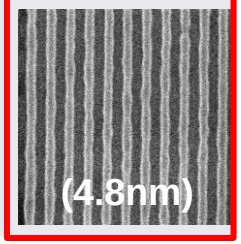


Small Field Exposure Tool (SFET)

ESR1	
Resolution (nm)	23
LWR (nm)	7.4
Sensitivity (mJ/cm^2)	14



N. Sugie et., al., EUVL sympo.2012

	DIW	Surfactant Rinse
Resolution (nm)	26	24
Sensitivity (mJ/cm2)	20.0	19.4
30nm L/S after Rinse (LWR)	 (6.2nm)	 (6.2nm)
30nm L/S after Post Rinse Bake (LWR)	 (6.6nm)	 (4.8nm)

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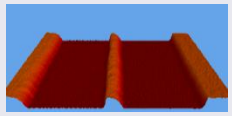
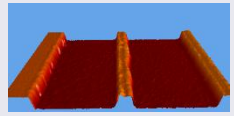
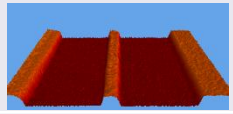
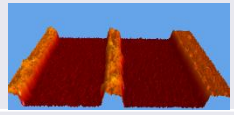
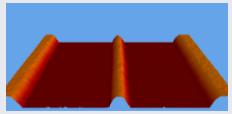
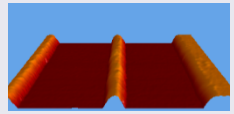
Resist	PHS-based	Hybrid
LWR (nm)	7.4	6.8
After devlop.	CD: 100% 	100% 
After rinse	100% 	160% 
After drying	100% 	101% 

J. Santillan et. Al., EUVL sympo.2012

Topics of Resist Material/Process Development

1. Update of the EIDEC Standard Resist
   - Focusing on negative tone development resist

2. Analysis of the Origin of RLS Trade-off on EUV Resist
   - Simulation study on the effect of material composition

3. Fundamental Study of Development Process
   - Analysis by High Speed AFM (HS-AFM)

1. Update of the EIDEC Standard Resist

◆ Positive tone resist

Motivation

- Establishment of RLS balance

⇒ ESR2

◆ Negative tone development resist

Expectation

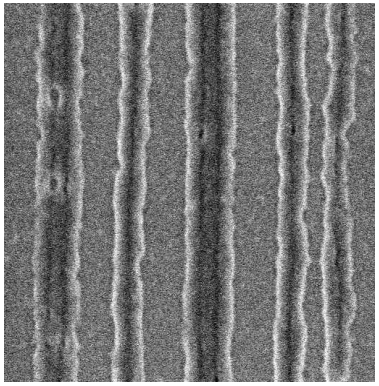
- High sensitivity for hole and/or trench patterns
- Improvement of LWR

⇒ ESR3

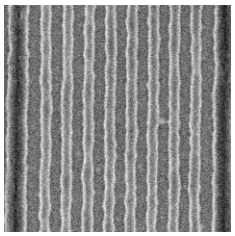
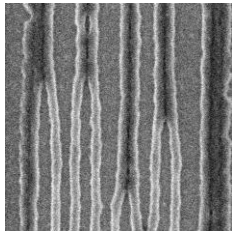
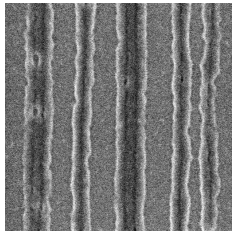
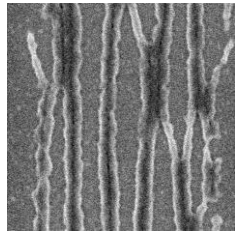
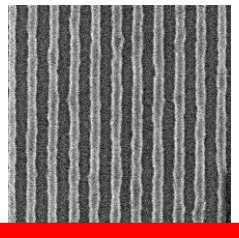
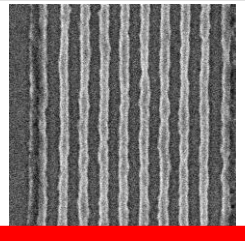
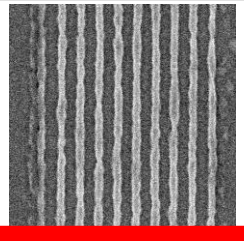
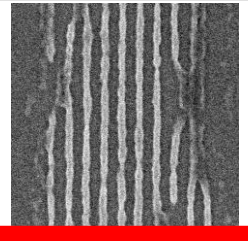
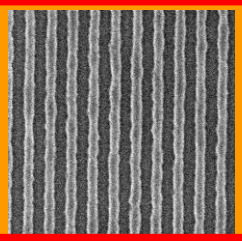
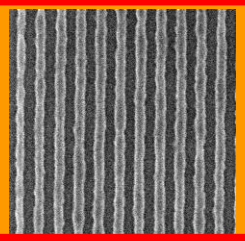
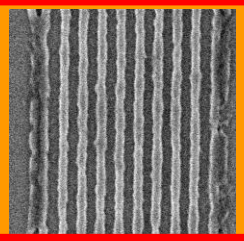
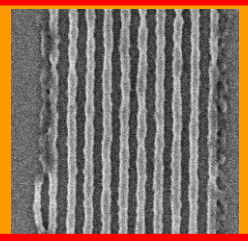
Process Investigation for NTD Resist

SFET Illumination : Annular
Resist Thickness : 50nm

Initial results



Pattern collapse

	32 nm hp	30 nm hp	28 nm hp	26 nm hp
Si with HMDS (reference)				
UL-A				
UL-B				

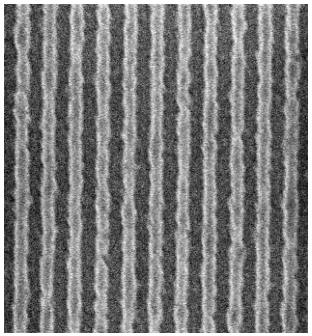
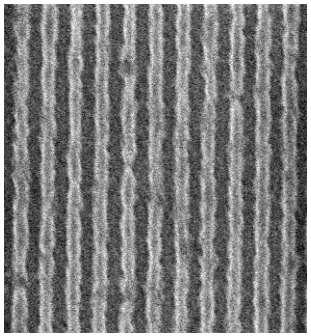
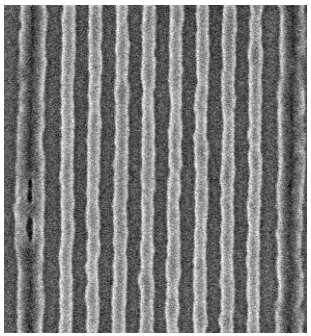
Improve collapse

- Pattern Collapse of NTD resist was improved by the application of under layer.

Takahashi et. Al., SPIE AL 2013

New EIDEC Standard Resists

SFET Illumination : Annular
Resist Thickness : 50nm

Resist		ESR1	ESR2 (New: Posi)	ESR3 (New: Nega)
Resolution	(nm)	25	26	28
LWR	(nm)	6.9	7.0	5.7
Sensitivity	(mJ/cm^2)	16.2	14.5	24.1
Top-Down SEM Image 30nm L/S (Mag. 200k)				

- New standard resists; ESR2 & ESR3 were selected.

Topics of Resist Material/Process Development

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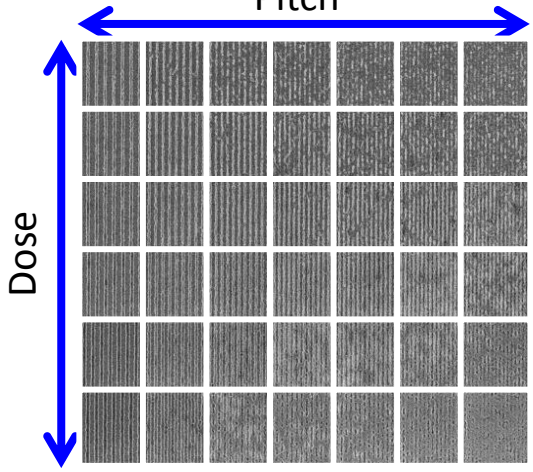
Simulation Protocol: Probability density model:

Input

Dose-pitch matrices



Actual CD, LER, sensitivity data measured with CD-SEM

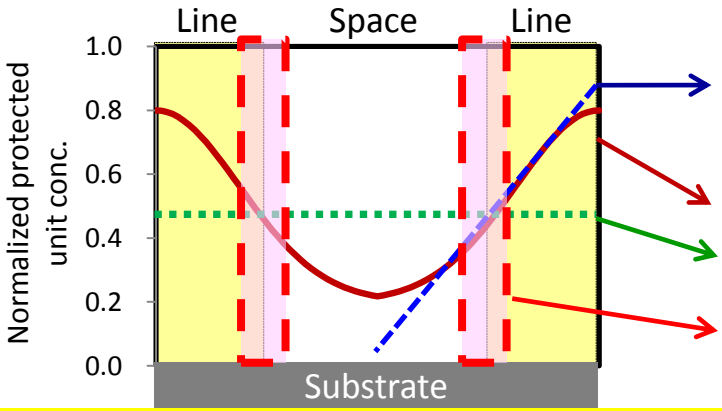
Simulation

Probability density model

Data base based on Prof. Kozawa work[1)]

Output

- Slope at the dissolution point (***dm/dx***: chemical gradient)
- Proportionality constant between LER and chemical gradient (f_{LER})
- Effective reaction radius for de-protection (R_p)
- Effective quencher concentration (Q conc.)



Slope at the dissolution point : *dm / dx* (chemical gradient)

Normalized protected unit conc.

Dissolution Point

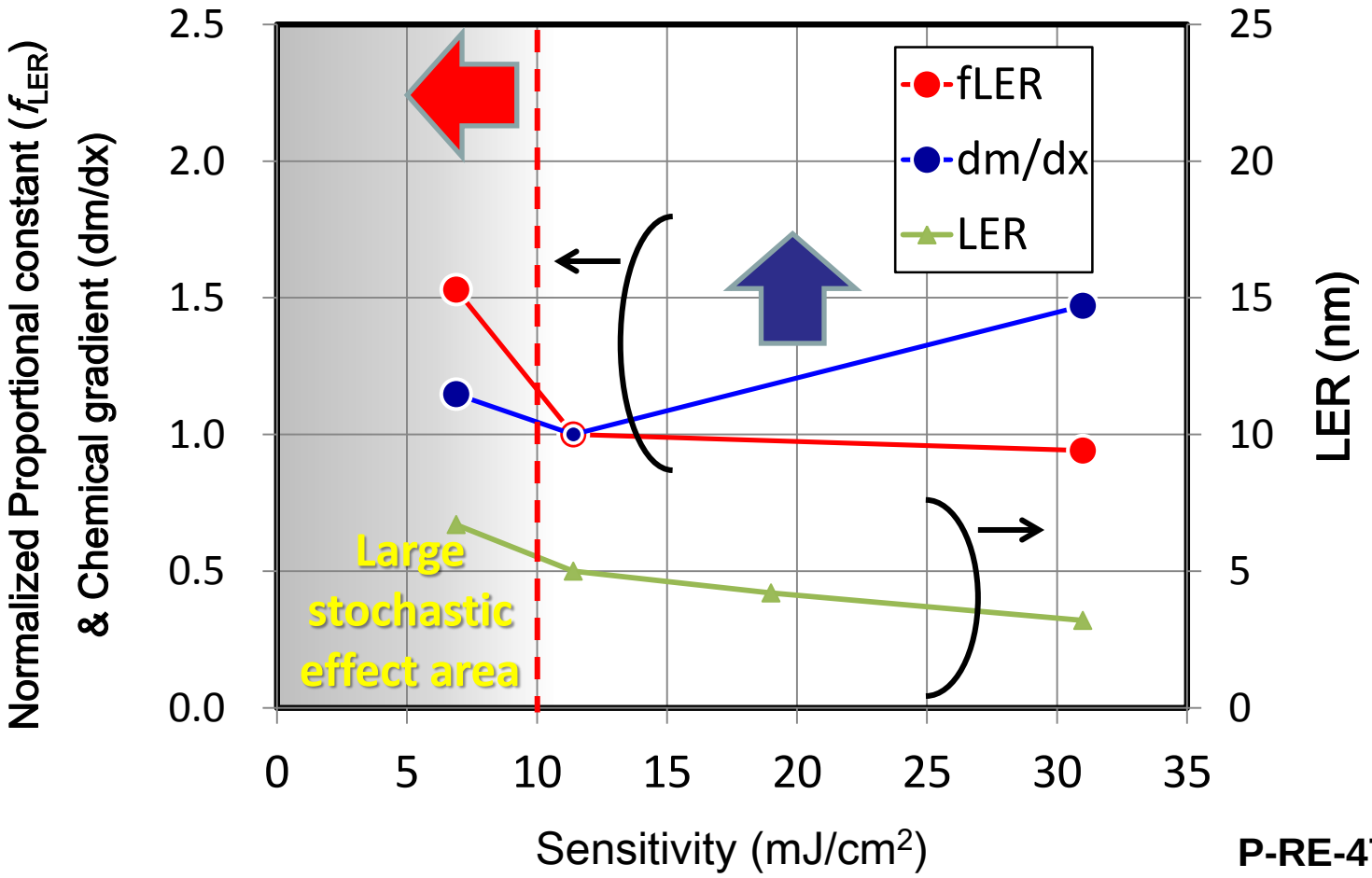
Mixture region

$$LER \approx \frac{f_{LER}}{dm / dx}$$

1) T. Kozawa *et al*.: *Jpn. J. Appl. Phys*. **49** (2010) 030001.

In this study, we simulated focused on probability density model.

LER vs. resist reaction parameters



$$LER \approx \frac{f_{LER}}{dm / dx}$$

P-RE-47: *Norihiko Sugie*

Constant f_{LER} region: High de-protection reaction efficiency, short acid diffusion length, and smooth development characteristics are necessary to break the RLS trade-off.

Large stochastic region: High absorption platform will reduce LER.

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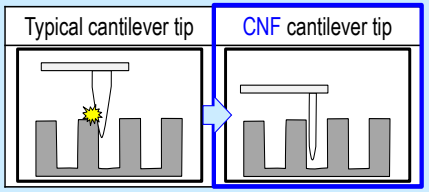
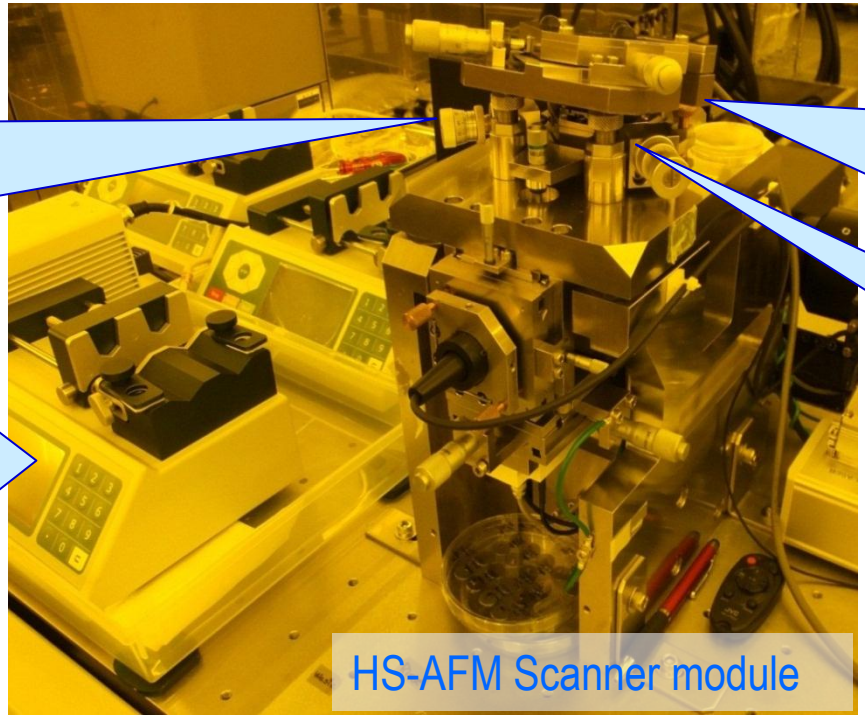
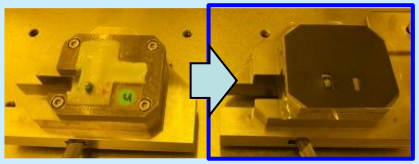
Improvements on HS-AFM Analysis

Cantilever
Narrower → stable scanning

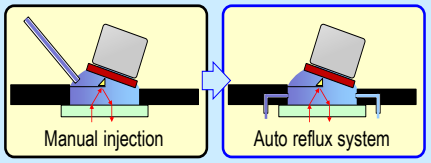




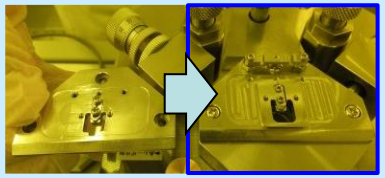
High resolution scanner
Ultra-sealed for solvent dev.



Auto reflux system
Improves solution-transfer stability during analysis



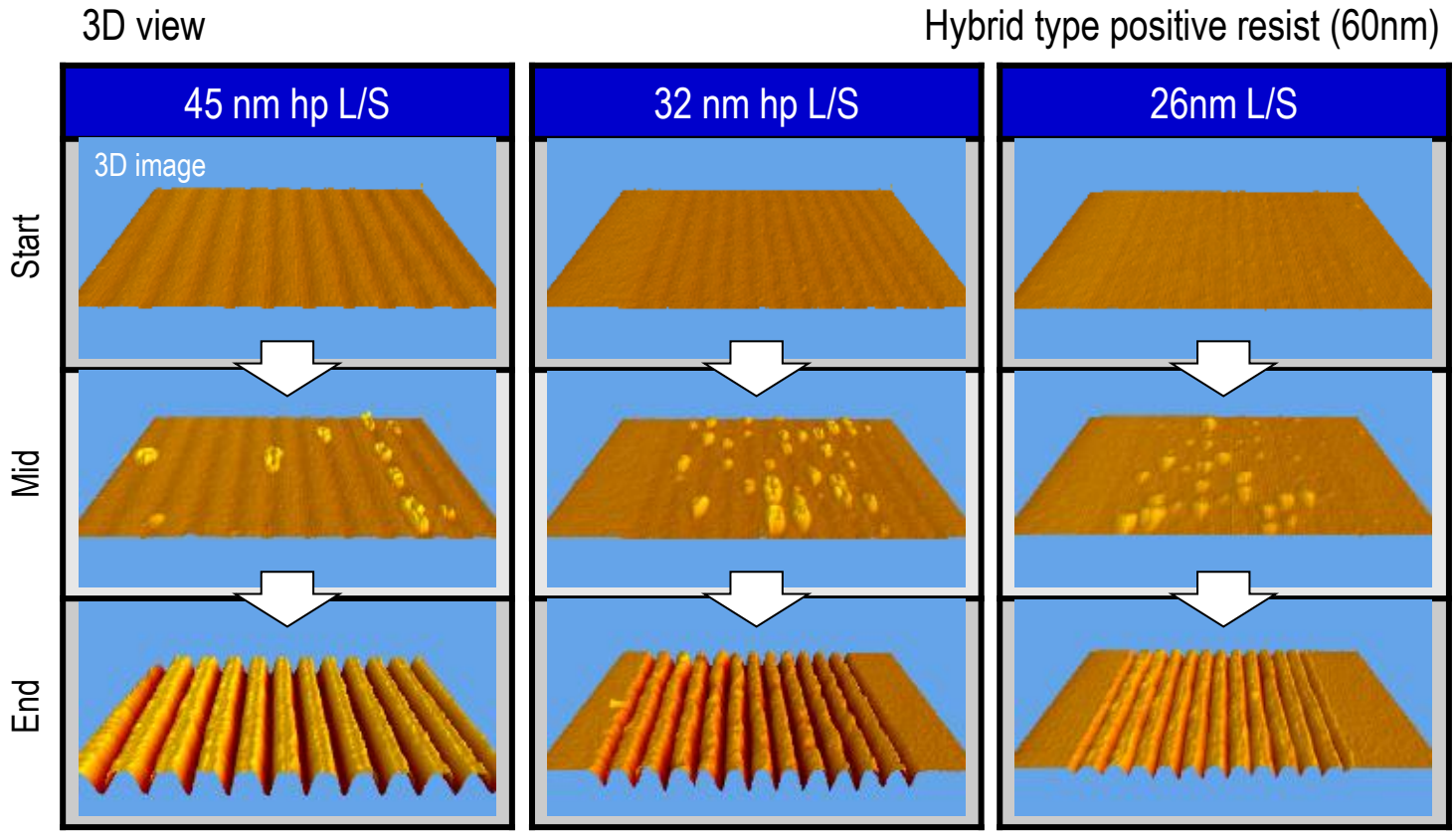
Cantilever/solution holder
Optimized for more stable scanning with solvent dev.



Analysis technique was customized for EUV resist characterization.

J. Santillan et. al ICPST 30, 2013

Dissolution Phenomenon of Dense L/S pattern



- Dissolution characteristics of patterns narrower than 32nm hp L/S obtained.
- Swelling characteristics observed for all pattern sizes.
- Scanning stability issues is still remaining as shallow trenches are formed.

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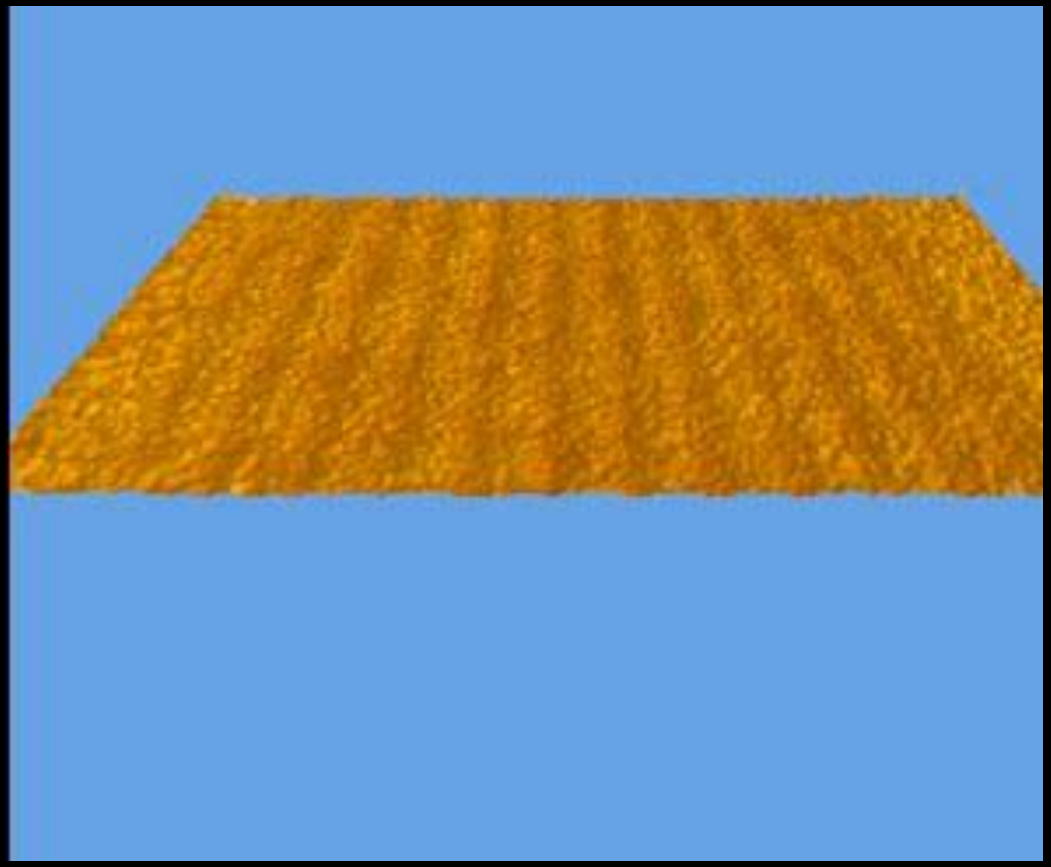
Development Phenomenon of NTD Resist



- Smooth patterns resolved with very minimal swelling of dissolving areas on negative tone development. P-RE-53:Julius Santillan

Summary

- EIDEC selected New Standard Resist ESR2 and ESR3 with good balance of lithographic performances.
- The origin of RLS trade-off on EUV Resist was analyzed by simulation of the effect of material composition.
- By using HS-AFM, 32 nm dense pattern and negative tone development resist was successfully observed.

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Acknowledgements

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- We would also like to thank:
  Prof. Kozawa for the valuable technical discussions and advices.
  EIDEC member companies for the continued support.
  Material suppliers for supplying the experimental materials.

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